

Lightning Strike Sensing System for the Space Shuttle Launch Pad

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Introduction: NRL Optical Sciences Division scientists designed and fabricated a fiber-optic magnetic field gradient sensing system for use by NASA on the space shuttle launch pad at Kennedy Space Center (KSC), Florida. The system is being used to monitor the occurrence and intensity of lightning strikes on and in the vicinity of the launch pad and space shuttle during prelaunch operations. The NRL system is integrated with the NASA Ground Lightning Monitoring System (GLMS), which records the intensity of the dynamic magnetic fields that result from lightning and triggers a warning if nearby lightning is strong enough to cause damage to the electronic systems employed on either the shuttle or the launch pad. Current lightning strike monitoring capabilities at the pad are not robust enough to screen lightning events, thus resulting in extensive, time-consuming inspections to verify the integrity of the electronic systems whenever any electrical storm activity occurs nearby. The NRL magnetic field gradient sensing system provides improved sensing bandwidth, resolution, and accuracy, and when incorporated into the GLMS, it alerts NASA as to when inspection of the electrical systems is required. Additionally, it indicates when inspection is not required, thus avoiding unnecessary expenditures of time and money.

System Description: The system has electronically passive, remote-sensing heads that are deployed both on the launch pad and aboard the space shuttle (Fig. 7). The use of passive sensors on the space shuttle launch pad is an important safety feature due to the presence of hydrogen and oxygen used to fuel the shuttle. Three search coils (X, Y, and Z axes) are used to generate dynamic voltages proportional to the time derivative of the local magnetic field as induced by lightning activity. This voltage is passed to an optical head that contains three fiber-optic interferometers (one for each vector axis of the magnetic field) where it is converted to optical phase. Three-by-three (inputs by outputs) optical couplers are used to form the interferometers; the voltage from the search coil is converted to optical phase by a crystal phase modulator in the sensing leg of the interferometer while the reference leg is left unperturbed. Demodulation of interferometers of this design does not require that an active carrier be imposed on the interferometer's output, thus maintaining

the passive nature of the sensing system. The optical heads containing the interferometers are connected by fiber-optic cables to an NRL avionics system in the instrumentation room located underground below the launch pad. These fiber-optic cables again maintain the electronically passive nature of the sensing system and are not susceptible to electromagnetic interference (EMI). The cables deployed on the launch pad are between 1 and 2 km in length; however, the system is capable of employing cables up to tens of kilometers long. Each NRL avionics box is configured to support up to four three-axis sensing heads. The system undergoes a 1-min autocalibration routine on power up and runs a continuous calibration update in the background during operation. Digital demodulation algorithms, with 5 MHz of processing bandwidth, are used to recover the dynamic magnetic waveforms from the optical carriers. These waveforms are passed to the NASA GLMS system.

Four NRL three-axis search coil sensors and the associated optical heads and avionics systems, all designed and fabricated by scientists and engineers in the Optical Sciences Division, were installed and tested by NRL and NASA personnel on Pad A at KSC in April 2008. The system has since undergone vigorous performance and acceptance testing. NRL and NASA engineers are collaborating to make system operational refinements that will optimize the system's lightning strike detection capabilities. On 31 May 2008, the system was used to monitor the intensity of lightning strikes that occurred near *Discovery* for the STS-124 mission. In December 2008, the NASA Engineering Readiness Review board approved the GLMS system, which employs the NRL Field Gradient Sensing system, for use on the space shuttle launch pad.

[Sponsored by NASA, Kennedy Space Center]



FIGURE 7
GLMS placement on the space shuttle *Discovery* launch pad.